

## **CHAPTER 4**

# **AN INTRODUCTION TO ALTERNATIVE TRANSPORTATION FUELS**

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## **4.1 INTRODUCTION**

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As discussed in Chapters 2 and 3, even with energy conservation transportation energy demand is expected to increase.<sup>1</sup> However, this demand need not be satisfied with petroleum. Alternative fuels<sup>2</sup> have the potential to satisfy some of this energy demand, and appear to offer some advantages over petroleum including:

- increased security of supply for alternative fuels made from local resources;
- lower air emissions; and
- beneficial effects on the local economy by retaining more energy dollars in Hawaii and creating jobs rather than exporting these funds to the countries that control the oil supply.

Because of their potential, alternative fuels merit a more detailed evaluation. This chapter introduces the alternative fuels that have been considered in this project,<sup>3</sup> describes past governmental efforts to support alternative fuels, and estimates the potential for substituting petroleum with alternative fuels.

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## **4.2 ALTERNATIVE TRANSPORTATION FUELS**

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This study addresses the following alternative fuels:

- alcohols: methanol and ethanol;
- natural gas and synthetic natural gas;
- propane (LPG);
- electricity;
- biodiesels; and

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<sup>1</sup> In the long term, increases in corporate average fuel economy (CAFE) standards could produce a decrease in demand compared to levels of the 1990's, but this is speculative.

<sup>2</sup> As used in this report, "alternative fuel" refers to any non-petroleum source of power appropriate for motor vehicle operation. This includes liquids and gaseous fuels as well as electricity. Consistent with the Energy Policy Act of 1992, propane is considered as an alternative fuel in this report as well. An "alternative fuel vehicle," as used here, refers to any vehicle specifically designed to run largely on an alternative fuel. More specific definitions can be found in the Energy Policy Act of 1992.

<sup>3</sup> The selection of which particular alternative fuels best satisfy Hawaii's energy goals and circumstances is deferred to Chapter 5.

- hydrogen.

Tables 4-1 and 4-2 summarize some key characteristics of the alternative fuels, and Tables 4-3, 4-4, and 4-5 list some alternative fuel vehicles (AFVs) which were built or were in production in mid-1993. Offerings of AFVs change quickly, so this information is provided only to give an example of AFV availability.

## **4.2.1 METHANOL**

### **4.2.1.1 Introduction**

Methanol,  $\text{CH}_3\text{OH}$ , is a liquid at room temperature. Since methanol was formerly produced from wood, it was commonly referred to as “wood alcohol.” Most methanol is now produced from natural gas (methane), although it can also be produced from biomass or by gasifying coal. At present, natural gas-based methanol is cheapest.

Total world production of methanol is currently about five billion gallons per year. This amount could power approximately five million automobiles. However, most methanol is used as a feedstock for plastics, copier fluid, windshield wiper fluid, antifreeze, model airplane fuel, and octane enhancer.

Methanol is an excellent motor vehicle fuel and has been used for many years in selected applications such as racing.<sup>4</sup> Its high octane value (over 100) permits its use in high compression, high output engines.

As a transportation fuel, methanol is used in the following forms:

- M100 (100 percent methanol);
- M85 (85 percent methanol, 15 percent gasoline);
- Methyl Tertiary Butyl Ether (MTBE), an oxygenate which can be blended in small amounts with gasoline and used in conventional vehicles to reduce emissions and enhance octane; and
- small amounts of pure methanol as an oxygenate in gasoline (typically five percent methanol).

Manufacturers have produced automobile, truck and bus engines that use methanol. M85 is commonly used in spark ignition automobile engines while M100 is used in compression ignition heavy-duty engines.

The Pacific International Center for High Technology Research and the Hawaii National Energy Institute are developing a demonstration-scale biomass gasifier on Maui to produce a fuel gas mixture from biomass, ultimately resulting in the production of methanol. A project funded primarily by the U.S. Department of Energy National Renewable Energy Laboratory and the State of Hawaii seeks to produce methanol from indigenous biomass.

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<sup>4</sup> Its high heat of vaporization provides air cooling that results in a “turbocharger” effect.

**Table 4-1**  
**Properties of Transportation Fuels**

Property	Gasoline	No. 2 Diesel Fuel	Methanol	Ethanol	MTBE	Propane	CNG (Methane)	Hydrogen
	Mixture of Hydrocarbons							
Chemical Formula	C <sub>4</sub> to C <sub>12</sub>	C <sub>3</sub> to C <sub>25</sub>	CH <sub>3</sub> OH	C <sub>2</sub> H <sub>5</sub> OH	(CH <sub>3</sub> )COCH <sub>3</sub>	C <sub>3</sub> H <sub>8</sub>	CH <sub>4</sub>	H <sub>2</sub>
Density, lb/gal @ 60°F	6.0-6.5 <sup>(b)</sup>	6.7-7.4 <sup>(d)</sup>	6.63 <sup>(b)</sup>	6.61 <sup>(b)</sup>	6.19 <sup>(m)</sup>	4.22	1.07 <sup>(r)</sup>	--
Boiling temperture, °F	80-437 <sup>(b)</sup>	370-650 <sup>(d)</sup>	149 <sup>(c)</sup>	172 <sup>(c)</sup>	131 <sup>(c)</sup>	-44	-259	-4,230 <sup>(u)</sup>
Reid vapor pressure, psi	8-15 <sup>(k)</sup>	0.2	4.6 <sup>(o)</sup>	2.3 <sup>(o)</sup>	7.8 <sup>(o)</sup>	208	2,400	--
Octane no.								
Research octane no. <sup>(1)</sup>	90-100 <sup>(u)</sup>	--	107	108	116 <sup>(t)</sup>	112	--	130+
Motor octane no. <sup>(1)</sup>	81-90 <sup>(s)</sup>	--	92	92	101 <sup>(t)</sup>	97	--	--
(R+M)/2 <sup>(1)</sup>	86-94 <sup>(s)</sup>	N/A	100	100	108 <sup>(t)</sup>	104	120+	--
Blending octane <sup>(w)</sup>	--	--	115 <sup>(7)</sup>	111 <sup>(8)</sup>	110 <sup>(9)</sup>	--	--	--
Latent heat of vaporization								
Btu/gal @ 60°F	900 (approx.) <sup>(b)</sup>	700 (approx.) <sup>(b)</sup>	3340 <sup>(b)</sup>	2378 <sup>(b)</sup>	863 <sup>(5)</sup>	775	--	--
Btu/lb @ 60°F	150 (approx.) <sup>(b)</sup>	100 (approx.)	506 <sup>(b)</sup>	396 <sup>(b)</sup>	138 <sup>(5)</sup>	193.1	219	192.1 <sup>(v)</sup>
Btu/lb air for stoichiometric mixture @ 60°F	10 (approx.) <sup>(b)</sup>	8 (approx.)	78.4 <sup>(b)</sup>	44 <sup>(b)</sup>	11.8	--	--	--
Heating value <sup>(2)</sup>								
Lower (liquid fuel-water vapor) Btu/lb	18,000-19,000	18,000-19,000	8,570 <sup>(b)</sup>	11,500 <sup>(q)</sup>	15,100 <sup>(h)</sup>	19,800	21,300	51,532 <sup>(v)</sup>
Lower (liquid fuel-water vapor) Btu/gal @ 60°F	115,000	128,400	56,800 <sup>(3)</sup>	76,000 <sup>(3)</sup>	93,500 <sup>(4)</sup>	84,500	19,800 <sup>(6)</sup>	--

Adapted from U.S.DOE, Energy Information Administration, Alternatives to Traditional Transportation Fuels: An Overview.

Notes:

<sup>(1)</sup> Octane values are for pure components. Laboratory engine Research and Motor octane rating procedures are not suitable for use with neat oxygenates. Octane values obtained by these methods are not useful in determining knock-limited compression ratios for vehicles operating on neat oxygenates and do not represent octane performance of oxygenates when blended with hydrocarbons. Similar problems exist for cetane rating procedures.

<sup>(2)</sup> Since no vehicles in use, or currently being developed for future use, have powerplants capable of condensing the moisture of combustion, the lower heating value should be used for practical comparisons between fuels.

<sup>(3)</sup> Calculated.

<sup>(4)</sup> Pour Point, ASTM D 97 from Reference (c).

<sup>(5)</sup> Based on Cetane.

<sup>(6)</sup> For compressed gas at 2,400 psi.

<sup>(7)</sup> At 5% in gasoline

<sup>(8)</sup> At 10% in gasoline

<sup>(10)</sup> At 15% in gasoline

Sources:

<sup>(a)</sup> The basis of this table and associated reference was taken from : American Petroleum Institute, *Alcohols and Ethers*, Publication No. 4261, 2nd ed. (Washington, DC, July 1988), Table B-1.

<sup>(b)</sup> \*Alcohols: A Technical Assessment of Their Application as Motor Fuels,\* API Publication No. 4261, July 1976.

<sup>(c)</sup> *Handbook of Chemistry and Physics*, 62nd Edition, 1981, The Chemical Rubber Company Press, Inc.

<sup>(d)</sup> \*Diesel Fuel Oils, 1987\*, Petroleum Product Surveys, National Institute for Petroleum and Energy Research, October 1987.

## Table 4-1 Properties of Transportation Fuels (Continued)

<sup>(e)</sup> ARCO Chemical Company, 1987.

<sup>(f)</sup> "MTBE, Evaluation as a High Octane Blending Component for Unleaded Gasoline," Johnson, R.T., Taniguchi, B.Y., Symposium on Octane in the 1980's, American Chemical Society, Miami Beach Meeting, Sept. 10-15, 1979.

<sup>(g)</sup> "Status of Alcohol Fuels Utilization Technology for Highway Transportation: A 1981 Perspective," Vol. 1, Spark-Ignition Engine, May 1982, DOE/CE-56051-7.

<sup>(h)</sup> American Petroleum Institute Research Project 44, NBS C-461.

<sup>(i)</sup> Lang's Handbook of Chemistry, 13th Edition, McGraw-Hill Book Company, New York, 1985.

<sup>(j)</sup> "Data Compilation Tables of Properties of Pure Compounds," Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, 1984.

<sup>(k)</sup> Petroleum Product Surveys, Motor Gasoline, Summer 1986, Winter 1986/1987, National Institute for Petroleum and Energy Research.

<sup>(l)</sup> Based on isooctane.

<sup>(m)</sup> API Monograph Series, Publication 723, "Teri-Butyl Methyl Ether," 1984.

<sup>(n)</sup> BP America, Sohio Oil Broadway Laboratory.

<sup>(o)</sup> API Technical Data Book - Petroleum Refining, Volume I, Chapter I. Revised Chapter 1 to First, Second, Third and Fourth Editions, 1988.

<sup>(p)</sup> "Automotive Gasolines," SAE Recommended Practice, J312 May 1986, 1988 SAE Handbook, Volume 3.

<sup>(q)</sup> "Internal Combustion Engines and Air Pollution," Obert, E.F., 3rd Edition, Intext Educational Publishers, 1973.

<sup>(r)</sup> Value at 80 degrees F with respect to the water at 60 degrees F (Mueller & Associates).

<sup>(s)</sup> National Institute for Petroleum and Energy Research, Petroleum Product Surveys, *Motor Gasolines, Summer 1992*, NIPER-178 PPS 93/1 (Bartlesville, OK, January 1993), Table 1.

<sup>(t)</sup> P. Dorn, A.M. Mourao, and S. Herbstman, "The Properties and Performance of Modern Automotive Fuels," Society of Automotive Engineers (SAE), Publication No. 861178 (Warrendale, PA, 1986), p. 53.

<sup>(u)</sup> C. Borusbay and T. Nejat Veziroglu, "Hydrogen as a Fuel for Spark Ignition Engines," *Alternative Energy Sources VIII, Volume 2, Research and Development* (New York: Hemisphere Publishing Corporation, 1989), pp. 559-560.

<sup>(v)</sup> *Technical Data Book*, Prepared by Gulf Research and Development Company, Pittsburgh, PA, 1962.

<sup>(w)</sup> *Properties of Alcohol Transportation Fuels*, Prepared for U.S. Department of Energy by Meridian Corporation, 1991.

**Table 4-2****General Comparison of Alternative Fuels**

<b>Fuel</b>	<b>Advantages</b>	<b>Disadvantages</b>
<b>Methanol</b>	<ol style="list-style-type: none"> <li>1. Could be produced locally from Hawaii materials ("feedstocks").</li> <li>2. Used for years in racing engines.</li> <li>3. California's AFV program has focused on methanol; extensive data available.</li> <li>4. Flexibly-fueled vehicles capable of operating on M85 (85% methanol, 15% gasoline), 100% gasoline, or any combination, are available from major auto manufacturers for the same price as gasoline vehicles.</li> <li>5. Bus &amp; truck engines which use 100% methanol are available from major manufacturers.</li> <li>6. High octane.</li> <li>7. Burns cleaner than gasoline.</li> </ol>	<ol style="list-style-type: none"> <li>1. Not yet locally available as a fuel.</li> <li>2. Price of methanol on a per-mile basis, in Hawaii, would currently be more than for gasoline. New methods of fuel production are expected to eventually make the fuel price competitive with gasoline and diesel.</li> <li>3. It takes 1.7 - 1.9 gallons of methanol to go as far as 1 gallon of gasoline.</li> <li>4. Imported methanol would predominantly be made from non-renewable natural gas.</li> </ol>
<b>Ethanol</b>	<ol style="list-style-type: none"> <li>1. Could be produced locally from Hawaii materials ("feedstocks").</li> <li>2. Can be blended (up to 10%) with gasoline and used in existing cars. Blending gasoline with 10% ethanol raises fuel octane about 3 points.</li> <li>3. Flexibly-fueled vehicles capable of operating on E85 (85% ethanol, 15% gasoline), 100% gasoline, or any combination, are available from major auto manufacturers for the same price as gasoline powered vehicles.</li> <li>4. Bus &amp; truck engines which use 100% ethanol are available from major manufacturers.</li> <li>5. Burns cleaner than gasoline.</li> <li>6. High octane.</li> <li>7. Non-toxic.</li> <li>8. Made from renewable sources.</li> </ol>	<ol style="list-style-type: none"> <li>1. Not yet locally available as a fuel.</li> <li>2. In order for ethanol to be blended (10%) in gasoline, the base fuel may need to be adjusted and blending equipment may need to be installed.</li> <li>3. Current market price of ethanol is more than for gasoline and diesel. New methods of fuel production from biomass are expected to eventually make the fuel price competitive with gasoline and diesel.</li> <li>4. It takes 1.3 - 1.5 gallons of ethanol to go as far as 1 gallon of gasoline.</li> </ol>
<b>Propane</b>	<ol style="list-style-type: none"> <li>1. Has been used in Hawaii as a transportation fuel for over 25 years; infrastructure in place.</li> <li>2. Conversions of existing vehicles and technical support are available locally.</li> <li>3. Light-duty trucks warranted for use with propane are available from major manufacturers.</li> <li>4. Reduced carbon monoxide emissions.</li> <li>5. High octane.</li> </ol>	<ol style="list-style-type: none"> <li>1. Fossil fuel based (refinery byproduct or natural gas reserves); non-renewable.</li> <li>2. Must be stored under pressure.</li> </ol>
<b>Natural Gas</b>	<ol style="list-style-type: none"> <li>1. Could be produced locally from Hawaii materials ("feedstocks").</li> <li>2. Bus and truck engines capable of operating on natural gas are available from major engine manufacturers.</li> <li>3. Burns cleaner than gasoline.</li> </ol>	<ol style="list-style-type: none"> <li>1. Fuel not locally available, and not economic to import to Hawaii.</li> <li>2. Compressed natural gas (CNG) has to be stored at very high pressure (2500 psi).</li> <li>3. Refueling equipment is expensive; refueling may take several hours.</li> <li>4. Liquefied natural gas (LNG) must be stored at very low temperatures, requiring special, insulated tanks (-260°F).</li> <li>5. It takes 3.6 gallons of CNG or 1.6 gallons of LNG to go as far as 1 gallon of gasoline.</li> </ol>
<b>Hydrogen</b>	<ol style="list-style-type: none"> <li>1. Extremely low emissions.</li> <li>2. Renewable; can be made from many different materials, including water.</li> </ol>	<ol style="list-style-type: none"> <li>1. In the research and development stage.</li> <li>2. Not yet commercially available.</li> </ol>

**Table 4-2 (continued)**

<b>Fuel</b>	<b>Advantages</b>	<b>Disadvantages</b>
<b>Electricity</b>	<ol style="list-style-type: none"><li>1. Electricity could be produced locally from Hawaii materials including biomass, solar or wind power.</li><li>2. A major part of the necessary infrastructure (electrical distribution system) is already in place.</li><li>3. Fuel cost is less per mile than gasoline or diesel.</li><li>4. Electric power plants and electric vehicles are more energy-efficient than internal-combustion engines.</li><li>5. No tailpipe emissions, and reduced overall emissions.</li><li>6. Charging at night (off-peak) would provide operational benefits to electric utilities which currently have a nighttime energy demand below their optimum minimum.</li></ol>	<ol style="list-style-type: none"><li>1. Currently available vehicles have range of less than 200 miles between charges.</li><li>2. Standards and infrastructure for battery charging and vehicle servicing are still under development.</li><li>3. Electric vehicles cost more than their gasoline counterparts; although higher volumes of production would reduce this difference.</li><li>4. Current electric-only vehicle technology is not appropriate for long distance heavy-duty truck and bus applications.</li><li>5. Disincentives to daytime charging from the grid must be put into place to avoid increasing demand for electricity during peak demand periods.</li></ol>
<b>Biodiesel</b>	<ol style="list-style-type: none"><li>1. Could be produced locally from Hawaii materials ("feedstocks") including waste cooking oils.</li><li>2. May be blended with regular diesel and used in existing diesel engines with minimal modification.</li><li>3. Biodiesel blends reduce emissions of particulates and smoke.</li><li>4. One gallon of biodiesel will go as far as one gallon of regular diesel.</li><li>5. Made from renewable sources.</li></ol>	<ol style="list-style-type: none"><li>1. Still undergoing testing and certification.</li><li>2. Not a gasoline replacement. For use in diesel engines only.</li><li>3. Retail price of biodiesel is much more than for regular diesel.</li></ol>

Source: State of Hawaii, DBEDT, 1993.

Note: For more information refer to the Hawaii Energy Strategy Project 2 (State of Hawaii, DBEDT, 1993).

**Table 4-3**

**Light- and Medium-Duty Internal Combustion Engine  
Alternative Fuel Vehicles**  
(listed vehicles have been built or were in production as of mid-1993)

<b>Fuel</b>	<b>Vehicle Type</b>	<b>Manufacturer</b>	<b>Model<sup>1</sup></b>
Methanol <sup>2</sup>	Minicompacts	Nissan	NX1600
	Subcompacts	Toyota	Corolla
	Compacts	Ford Mazda Nissan Volkswagen	Escort Protege Stanza Jetta('92)
	Mid-Size Sedans	Chrysler  Ford General Motors  Mitsubishi Volvo	Concorde Dodge Intrepid Dodge Spirit ('92, '93) Eagle Vision Plymouth Acclaim ('92, '93) Taurus ('91, '93) Chevrolet Corsica Chevrolet Lumina ('91, '92, '93) Galant 940
	Luxury Sedans	Mercedes	300S
	Station Wagons	Ford	Crown Victoria ('89, '90)
	Vans	Chrysler Ford	Plymouth Voyager Econoline ('92)
Natural Gas	Passenger Cars	Chevrolet	Caprice (conversion-ready)
	Station Wagons	Chrysler Ford	Dodge B-Series Crown Victorias
	Vans	Chrysler Ford	Dodge B-Series Forthcoming
	Pick-Up Trucks	Chevrolet Chevrolet Ford GMC GMC	C1500-Series C2500-Series Ranger Sierra 1/2 ton Sierra 3/4 ton
	Medium Duty Trucks	Ford	F-Series
Propane	Station Wagons	Chevrolet	Suburban 5.7L
	Vans	Chevrolet Ford	5.7L engine Econoline E150/E250
	Pick-up Trucks	Chevrolet	3/4 and 1 ton
	Medium Duty Trucks	Chevrolet GMC Ford	366/427 CID engines 366/427 CID engines 429 CID engine

Notes:

- 1) Model Year information is shown for vehicles which have been produced in volumes of 100 or more.
- 2) Vehicles are marketed as methanol vehicles. Vehicles designed for methanol may operate on ethanol with minor adjustments. GM, Ford and Volkswagen have completed necessary testing for calibration.



**Table 4-4**

**Electric Vehicles**  
**(listed vehicles were under development,**  
**have been built, or were in production as of Mid-1993<sup>1,2</sup>)**

<b>Class of Manufacturer</b>	<b>Vehicle Type</b>	<b>Manufacturer</b>	<b>Model</b>
These Original Equipment Manufacturer (OEM) vehicles are under development and some are expected to be available for sale to the public around 1998	Passenger Cars	BMW Chrysler EPIC Fiat  Ford Commuter Car General Motors Mazda Nissan Peugeot Renault  Volkswagen Volvo	E1 (Europe), E2 (U.S.) EPIC Panda Elletra, Cinquescent Ellectra  No model yet identified Impact Miata Cedric, FEV Model 106 size Zoom, Master, Express, Electro-Clio Chico, Golf/Jetta Gas turbine hybrid concept car
	Vans	Chrysler Ford GM Peugeot Renault	TEVan Ecostar Conceptor G-Van small van Express Van
Small EV Producers	Passenger Cars	AC Propulsion  California Electric Cars Solar Car Corp. Solectria U.S. Electricar	ELX (converted Honda CRX) 2-person sports car  Festiva Electric Converts new & used Force (converts new 2 & 4 seaters)
	Pick-Up Trucks	Solar Car Corp.	Converts mainly Ford
	Shuttle Buses	Bus Manufacturing USA Clean Air Transit Nordskog Manufacturing Eldorado	Forthcoming  22-passenger 22- and 26-passenger 22-, 26-, and 31-passenger
	Three-Wheelers or Other Small Specialty Vehicles	Cushman Nordskog Sebring Auto-Cycle Taylor-Dunn Suntera	500 lb capacity Various Zipper Various

Notes:

- 1) Prototype electric versions of models other than those listed here may have been developed at one time. (e.g. Mazda has developed over 70 prototype EVs since the 1970s.)
- 2) This is not a complete list. Virtually all major manufacturers have EV programs and a large number of small manufacturers or converters exist of which only a few are represented here. In addition, many component manufacturers exist and are not listed here.

**Table 4-5**

**Medium- and Heavy-Duty Alternative Fuel Engines**  
**(listed vehicles were available as of mid-1993 as production models,**  
**or were expected to be in production in the next several years**  
**in the absence of specific regulatory or economic impetus<sup>1)</sup>)**

<b>Fuel</b>	<b>Manufacturer</b>	<b>Engine</b>	<b>Typical Application</b>
Methanol <sup>2</sup>	DDC	6V-92TA, 253HP* 6V-92TA, 277HP* 6L-71TA 4L-71TA	Urban Bus, Some Off-Road Urban Bus, Some Off-Road Primarily Off-Road Primarily Off-Road
Ethanol (E95)	DDC	6V-92TA, 253HP* 6V-92TA, 277HP*	Urban Bus, Some Off-Road Urban Bus, Some Off-Road
Natural Gas	Caterpillar  Cummins  DDC   GM Tecogen/GM Hercules  Mercedes-Benz Navistar Tecogen Volvo Bus Corp.	3306, 250HP 3406, 350HP L10, 240HP L10, 270HP 6B, 195HP 6V-92TA, PING 253HP 6V-92TA, DING 253HP 6V-92TA, PING 277HP 6V-92TA, DING 277HP 6V-92TA, PING 300HP 6V-92TA, DING 300HP 8.2L, 175HP 4.27, 213HP 3.7L, 130HP 5.6L, 190HP M 366G, 148HP 7.3L, 210HP TecoDrive 7000 9.9L, 250HP	
Propane	Ford  GM   Iveco Mercedes	429 CID Truck F-600 F-700 366/427 CID Truck 5.7L, pick-ups, vans, suburbans, Convert on delivery 240HP 220HP	

Notes:

- 1) Based on conversations with OEMs, only DDC will supply alcohol heavy duty engines in the absence of large demand. DDC has essentially no lower production limit. Caterpillar and Navistar, the two other OEMs well positioned to offer methanol engines, are not yet certified and would only respond to a large demand, on the order of thousands of sales per year.
  - 2) DDC engines certified on M100, M85, and M99 with 1% avocet.
- \* Engines are fully certified and available for sale.

In addition, since methanol can be produced by the gasification of coal, the Hawaiian Electric Company (HECO) has studied the installation of a coal gasifier at the Kahe Point station which could produce methanol using Babcock and Wilcox technology.

Technology for the commercially successful production of methanol from biomass may be ready in the near- to mid-term. The production scale of commercially feasible biomass to methanol facilities is expected to be relatively large (on the order of 100 million gallons per year) to spread the cost of the necessary equipment over a relatively large volume.

#### **4.2.1.2 Methanol Vehicle Availability by Sector**

##### **4.2.1.2.1 Ground Sector**

In the 1980s, manufacturers began to deploy small numbers of methanol cars, particularly in California where interest in very low emission vehicles encouraged a detailed look at clean alternative fuels. Methanol appeared to have a chance of becoming an acceptable substitute for gasoline based on its performance and projected cost. However, as these vehicles were “dedicated” vehicles which could not operate on gasoline, they did not attract much user interest due to the limited number of methanol refueling stations and their reduced range.<sup>5</sup>

The adoption of the Alternative Motor Fuels Act credits in 1988 (the Alternative Motor Fuels Act is discussed in Section 4.3.1) added impetus to interest in methanol. Flexible-fuel<sup>6</sup> technology developed as a response to limited methanol availability at refueling stations. In 1988, the Department of Business, Economic Development and Tourism (DBEDT) and the Hawaii Natural Energy Institute (HNEI) began a demonstration of seven M85 vehicles. Ford deployed 210 flexible-fuel Crown Victorias in California and elsewhere in 1989 and 1990 and 180 1991 flexible-fuel Taurus sedans. GM placed 200 1991 Chevrolet Luminas. Volkswagen placed slightly more than 300 flexible-fuel Jettas. In 1992, Ford provided 200 flexible-fuel Econoline vans or Club Wagons, and Chevrolet placed 1,200 flexible-fuel Lumina sedans. Other manufacturers provided small numbers of vehicles as well.

In 1993, Chrysler won a major contract with the General Services Administration (GSA) under the Alternative Motor Fuels Act for 2,500 flexible-fuel Plymouth Acclaim and Dodge Spirit sedans, of which 500 were to be deployed in California. Ford also accepted orders for 2,500 1993 Taurus sedans, and Chevrolet and Chrysler had campaigns to place as many Luminas, Acclaims, and Spirits as possible. Orders for these cars may have amounted to roughly 1,000 vehicles. Prior to these introductions, about 8,000 methanol fuel flexible vehicles (FFVs) were operating in California. Also in 1993, DBEDT and HNEI began another methanol FFV demonstration program.

In the 1995 model year, Ford offered the Taurus in both ethanol-and-methanol-flex fueled versions. Chrysler offered the Dodge Spirit, Plymouth Acclaim and Dodge Intrepid. Manufacturers have been vague about future plans. Privately, they indicate that the need to demonstrate flexible-fuel technology has been met, and that customer responses have been studied to an extent sufficient to plan future marketing strategies. Continued manufacture of

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<sup>5</sup> Unless the manufacturer supplies a larger fuel tank, methanol vehicles tend to have a reduced range because the energy density of methanol is about half that of gasoline.

<sup>6</sup> A flexible-fuel (or variable-fuel) vehicle is one that can burn variable blends of two or more fuels.

2,000 to 4,000 FFVs per year is not economical. Thus, although manufacturers could supply a substantial number of methanol/gasoline light-duty vehicles, they will not be likely to do so except to meet the Energy Policy Act (EPACT) requirements which began in the 1993 model year. Given these observations, it is the conclusion of most observers that the automakers would devote themselves to preparing for the government fleet sales requirements of EPACT.

Methanol engines and vehicles are also available in the heavy-duty sector. Detroit Diesel Corporation (DDC) produces methanol 6V-92TAs. The 253 horsepower (hp) and 277 hp versions are emission-certified on M85, M100, and M99 with one percent Avocet.<sup>7</sup> This engine dominates the urban bus market.<sup>8</sup> DDC has stated it would sell even small numbers of methanol 6V-92TAs each year because its development costs have been spent and its strategy is now to sell such engines even in small numbers (Miller, 1993).

Vehicles are less available between 6,000 pounds and 26,000 pounds (classes 3 through 6). This may be rectified to some degree by DDC's recent development of a methanol/Avocet version of their 4-71 engine which, as part of a demonstration program, will be installed in 10,000 pound to 12,000 pound school buses in Sacramento.<sup>9</sup> DDC has stated that suitable methanol engines could be commercialized quite easily with sufficient demand (Miller, 1993).

Other manufacturers such as Caterpillar and Navistar<sup>10</sup> have developed to near-commercial stages methanol versions of heavy-duty engines that serve a large segment of the truck market. However, they do not expect to make these engines commercially available because they do not see a growing market for heavy-duty methanol vehicles and need an annual demand of thousands of engines before committing to production (Baranescu, 1993; Gove, 1993).<sup>11</sup>

#### **4.2.1.2.2 Air And Marine Sectors**

Ship engines could be designed to operate on methanol, but since alcohols are miscible with water, there is concern that, on-board a ship, water would contaminate an alcohol fuel and introduce salt into the engine. In addition, regulations have not been established nor are expected which would require alternative fuel engines for marine applications. With respect to alcohol-fueled aircraft, the focus is on ethanol (see Section 4.2.2).

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<sup>7</sup> Avocet is a proprietary additive package that includes an ignition improver, a lubricating additive, and a corrosion inhibitor.

<sup>8</sup> The 6R-92TA engine is appropriate for Class 7 and Class 8 trucks. However, it is not currently sold into the truck market. DDC is attempting to break into the truck market with this methanol engine and has 300 hp and 350 hp versions of the methanol 6V-92TAs operating in the current California Energy Commission (CEC) heavy-duty truck demonstration in Southern California. DDC is also demonstrating a methanol 300 hp 6L-71 engine as part of the CEC program, but this engine series is not typically found in trucks either. Both engines are used to power off-road equipment.

<sup>9</sup> The 4-71 is typically used in off-road equipment.

<sup>10</sup> Methanol versions of the diesel 3306 and 3406 DITA engines have been developed and demonstrated. A methanol DT-466 has been developed and demonstrated.

<sup>11</sup> There have been difficulties reported during the Los Angeles County Metropolitan Transportation Authority's methanol transit bus demonstration program, the nation's most ambitious methanol bus program. However, a staff assessment has concluded that the mechanical difficulties associated with the introduction of the methanol buses were not substantially different or more serious than mechanical difficulties experienced in the past with the introduction of a new diesel bus design. Few of the problems were fuel-related.

#### **4.2.1.3 Conclusions**

For the purpose of this analysis it is assumed that enough methanol flexible-fuel light duty vehicles will be available through the 1990s to satisfy fleet demands under the AFV purchase requirements of EPACT.<sup>12</sup>

### **4.2.2 ETHANOL**

#### **4.2.2.1 Introduction**

Ethanol,  $\text{CH}_3\text{CH}_2\text{OH}$ , is produced from ethylene or biomass. Ethylene is derived from natural gas or petroleum in large volumes worldwide. Biomass has been fermented to produce ethanol for thousands of years. Any substance which contains sugar or can be converted to sugar (such as starch or cellulose) may be used as the biomass feedstock. In addition to being used as a fuel and as a beverage, ethanol can be used as a solvent or in the manufacture of drugs, plastics, lacquers, perfumes, and other products (Encyclopedia of Chemical Toxicology, 1980).

Like methanol, ethanol is well suited to be a motor fuel. Its high octane permits its use in high compression engines, resulting in increased efficiency and power output. Ethanol can be used in motor vehicles in a number of forms, including:

- Gasohol or E10 (ten percent ethanol, 90 percent gasoline);
- "Diesohol" or E30 (30 percent ethanol, 70 percent diesel);<sup>13</sup>
- E85 to E95 ("neat ethanol") (85 percent to 95 percent ethanol, five percent to 15 percent gasoline or other hydrocarbon); and
- Ethyl Tertiary Butyl Ether (ETBE), an oxygenate made from ethanol which can be blended in small amounts with gasoline to reduce emissions and enhance octane.

The United States produced about 875 million gallons of fuel ethanol in 1991 and has been exporting fuel ethanol to Brazil since 1989.<sup>14</sup>

One inoperative ethanol plant now exists in the state on Maui. The facility was originally built for rum manufacture but has been inoperative since 1985. The capacity of the plant is about one million gallons of ethanol per year. A two million gallon per year facility, originally built for ethanol production but later used to make rum from molasses, was built in 1985 at Campbell Industrial Park on Oahu. This facility was recently dismantled (Shigeta, 1993).

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<sup>12</sup> These purchase requirements are considered to be modest, and are discussed in more detail in Section 4.3.1.

<sup>13</sup> Diesohol is not yet a proven fuel. Preliminary work indicates that a blend of 30 percent ethanol and 70 percent diesel, including some additives, could be used directly in an unmodified diesel engine (Holland *et al.*, 1992).

<sup>14</sup> In 1975, Brazil embarked on a large program to displace petroleum in their ground transportation sector by ethanol, and has been able to achieve 50 percent substitution. There are now more than four million ethanol vehicles in Brazil.

Prospects for ethanol production in Hawaii may now be brighter because of such factors as the following:

- Since sugar cane is a good feedstock for ethanol, the infrastructure for cane production already exists, and gasoline blended with low levels of ethanol may be used in unmodified gasoline engines, ethanol production is seen by some as a near-term way to support the agriculture industry.
- Grants from the National Renewable Energy Laboratory were recently awarded to the Pacific International Center for High Technology Research in association with others<sup>15</sup> to evaluate new technology for ethanol production from bagasse in Hawaii.
- Entrepreneurs continue to approach the state for support in developing ethanol facilities.

The commercial feasibility of ethanol production is related to the price of petroleum and technological improvements to increase yield. Policy aspects of state support for ethanol production are discussed further in Chapter 10.

#### **4.2.2.2 Ethanol Vehicle Availability by Sector**

##### **4.2.2.2.1 Ground Sector**

The vehicle technology for methanol and ethanol is essentially the same, differing only in the calibration of the fuel delivery system and fuel composition sensor (Barnes, 1993).<sup>16</sup>

In fact, converting a methanol vehicle to run on ethanol would only involve essentially software changes. The conversions could potentially be performed at a dealer's shop.<sup>17</sup>

General Motors (GM), Ford and Volkswagen have completed the testing necessary to optimize their FFVs to run on E85. GM provided 50 flexible-fuel Chevrolet Lumina calibrated for ethanol operation that are being demonstrated in the Midwest, and converted two M85 vehicles for the California program. Volkswagen produced 1992 Jettas that would run on E85. Ford's 1995 Taurus is available with methanol and ethanol flexible fuel options. In 1996, GM will offer ethanol flexible-fuel pickup trucks.

Gasoline blended with low levels of ethanol (gasohol) can be used in unmodified engines. Gasohol use has been widespread since the oil crisis of the 1970's, and all major vehicle manufacturers include gasohol under their warranty coverage (State of Hawaii, Department of Business, Economic Development and Tourism, 1991). Another way to incorporate relatively low levels of ethanol into unmodified engines is through ETBE, a fuel oxygenate that satisfies air quality requirements on the mainland.

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<sup>15</sup> AMOCO, Cargill, C. Brewer, HELCO, HEI, Hawaii County, UH, HNEI and the Hawaii Agricultural Research Corporation.

<sup>16</sup> Three-way FFVs (methanol, ethanol and gasoline) could perhaps be developed. SAAB has performed research, but efforts have been frustrated by the need for a fuel composition sensor capable of measuring relative amounts of ethanol, methanol, and gasoline (Barnes, 1993).

<sup>17</sup> The conversion would include changing the "chip" that integrates the signal from the alcohol sensor with engine performance. The manufacturer's cost of conversion may be \$40, especially if large numbers of vehicles were being converted.

Preliminary indications are that a blend of 30 percent ethanol and 70 percent diesel (“diesohol”) could be used in unmodified diesel engines.<sup>18</sup> Full-scale durability and field testing has not yet occurred, however (Earle, 1993).

DDC has certified its 253 hp and 277 hp 6V-92TA for E95. Fourteen transit buses using this engine are in operation in Peoria, Illinois. Little ethanol development of heavy-duty truck engines has occurred, however.

#### **4.2.2.2.2 Air And Marine Sector**

Ethanol engines for marine vessels are not expected for the reasons described in Section 4.2.1.2.2. Recently, however, an aircraft engine series was certified on ethanol.<sup>19</sup> It is not expected, however, that aircraft regulations would encourage the production of alternative fuel aircraft engines on a significant scale.

#### **4.2.2.3 Conclusions**

Because of the basic convertibility of methanol and ethanol FFVs, the availability of ethanol FFVs could match the availability of methanol FFVs. However, a petroleum substitution strategy has to adapt to the vehicles that manufacturers provide, and of the two alcohols, most FFVs are being manufactured for methanol.

### **4.2.3 NATURAL GAS AND SYNTHETIC NATURAL GAS**

#### **4.2.3.1 Introduction**

Commercial natural gas is a blend of gases, mostly methane (CH<sub>4</sub>) but also ethane, propane, butane and small amounts of other gases.

Most natural gas is produced from oil and gas-producing wells. Methane is also produced by the anaerobic decomposition of biomass, such as occurs in landfills and sewage treatment plants. Sometimes this methane is recovered and used.

Natural gas is an excellent vehicle fuel, burning very cleanly with a high octane value permitting efficient high-compression engines. However, it is difficult to store enough natural gas on a vehicle to provide adequate range. Since the amount of energy in a cubic foot of natural gas at ordinary pressure is very low, the gas must either be stored as compressed natural gas (CNG) at very high pressures (generally between 2,400 pounds per square inch and 3,600 pounds per square inch), or as liquefied natural gas (LNG) at very low temperatures. Therefore, natural gas appears best suited for medium-duty and heavy-duty trucks and buses, where fuel storage volume is more easily provided than in smaller vehicles.

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<sup>18</sup> Greenbranch Enterprises has performed testing of this blend, which includes a proprietary additive, with favorable results.

<sup>19</sup> Researchers at Baylor University in Waco, Texas, certified an aircraft engine series on ethanol in March, 1990. FAA certification is required for an engine to be used in civil commercial applications. The engine used for testing was a 260 horsepower (2,700 rpm) Avco Lycoming AE11O-540 D4A5 engine with 6 cylinders, parallel valves, and fuel-injection (Ninth International Symposium on Alcohol Fuels, Volume 2).

Hawaii does not have natural gas. Oahu has a fuel gas locally known as “synthetic natural gas” or SNG. This gas is distributed by pipeline to a relatively small number of customers in a limited area of Honolulu.

The chemical composition of local SNG is highly variable, being a blend of refinery byproducts in stock at the time mixed to achieve a relatively constant energy content. This SNG could not be used as a motor fuel. Although some methane could be produced from landfills and sewage treatment plants, volumes would be small and the methane would not have the competitive pricing with petroleum that it has on the mainland. Natural gas on a commercial scale would need to be imported, and the development of infrastructure to support the importation of natural gas is not expected (State of Hawaii, DBEDT, 1993).

#### **4.2.3.2 Natural Gas Vehicle Availability by Sector**

##### **4.2.3.2.1 Ground Sector**

Manufacturers believe that on the mainland, natural gas will be a formidable competitor of petroleum outside of the light-duty passenger automobile category.<sup>20</sup> Therefore, the manufacturers are beginning to offer a fairly wide range of buses, vans, wagons, and pick-up trucks. Hundreds of transit buses around the nation are now operating on natural gas.<sup>21</sup> Chrysler plans to supply natural gas vans and wagons in the B250/B350 series and Chevrolet will supply C1500 series pick-up trucks (gross vehicle weight 6,100 pounds). Cummins has recently certified in California a natural gas version of its L10 engine.

Ford has shown several natural-gas versions of the Crown Victoria sedan, and Chevrolet will also supply several thousand natural gas versions of the compact Corsica sedan.<sup>22</sup> However, the ability to store sufficient fuel onboard is a significant problem for passenger cars. Ford recently announced a \$50 million program to develop dedicated natural gas passenger cars by the mid 1990s, but these cars would not go into production for several years (New Fuels Report, 1993).

##### **4.2.3.2.2 Air And Marine Sector**

A few natural gas vessels are or will soon be operating around the U.S.: an LNG supply boat and CNG crew boat are in construction in Santa Barbara, California, and a CNG ferry boat is in operation on the Chesapeake Bay. However, no factors are motivating the production of natural gas-fueled marine engines. There are rumors of an LNG-fueled U.S. military jet (Spy in the Sky, 1992).

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<sup>20</sup> It appears likely that EPACT requirements for fleet purchase requirements in the light-duty truck sector from about 4,000 pounds gross vehicle weight (GVW) to the EPACT upper limit of 8,500 pounds GVW will be met primarily by natural gas and propane. EPACT's requirements are described in Section 4.3.1.

<sup>21</sup> For example, Sacramento Regional Transit recently acquired 75 new buses powered by Cummins L10 CNG engines. Houston Metro currently operates 60 LNG transit buses (Houston Metropolitan Transit Authority, 1993). The Metropolitan Transit Authority in New York City operates CNG buses.

<sup>22</sup> Each Corsica will have, in addition to the conventional gasoline tank, a storage capacity for natural gas equivalent to four gallons of gasoline. This apparently illogical product, having such a limited onboard storage capacity for natural gas, is interpreted as a response to GSA desires to fill out the orders in the 1993 EPACT procurement with natural gas vehicles.



#### **4.2.3.3 Conclusions**

Natural gas vehicles will be available in increasing number and model lines in weight classes around 6,000 pounds and over from now through 2014. However, with no natural gas supply system likely to be developed in Hawaii, natural gas AFVs do not appear feasible here. The lack of a role for natural gas vehicles in Hawaii is a significant difference from the alternative fuel picture that is developing on the mainland.

#### **4.2.4 PROPANE**

##### **4.2.4.1 Introduction**

Commercial LPG, a blend of propane ( $C_3H_8$ ) and other liquid hydrocarbons, is commonly referred to as simply "propane". Hawaii consumes about 30 million gallons of commercial propane each year, most of which is produced as a refinery byproduct, but some of which is imported (Freeman, 1992). Imported propane is also a refinery byproduct but can also be produced from liquids obtained from gas and oil wells. In Hawaii, propane is trucked to storage tanks for pipeline distribution for cooking, water heating, and other uses. Propane is also dispensed in small containers to serve other fueling needs, such as barbecue grills. If all of this propane were used as a vehicle fuel, it could power about 50,000 light-duty vehicles.

Propane is an excellent motor fuel. It is clean burning and has a high octane value. Although it is a gas at room temperature and normal pressure, it condenses to a liquid at pressures around 100 pounds per square inch and is therefore readily storable in simple metal bottles. It has an energy density similar to that of gasoline, and therefore does not produce a significant range penalty compared with an equal volume of gasoline. In contrast to the mainland, propane in Hawaii is slightly more expensive than gasoline per unit of energy.

Vehicles can be built to use propane, or gasoline vehicles can be converted to burn propane. The cost of a propane conversion is about \$1,200 to \$2,000 per vehicle.

There are roughly 400,000 propane vehicles in the U.S., and perhaps as many as 3,000 in Hawaii (Freeman, 1992) including school buses, Handi-Van vehicles, cars, trucks, airport support vehicles and forklifts. The City and County of Honolulu has 30 years of experience with propane in transportation, and presently there are 139 city vehicles, or 11.5 percent of the City's fleet, using propane.

In the drafting of the Alternative Motor Fuels Act, propane was regarded as primarily a petroleum product rather than a true alternative fuel. This interpretation was changed in the 1992 National Energy Policy Act and propane was made eligible for the incentive treatment in the calculation of corporate average fuel economy (CAFE).

#### **4.2.4.2 Propane Vehicle Availability by Sector**

##### **4.2.4.2.1 Ground Sector**

Original equipment manufacturers<sup>23</sup> (OEMs) offered a few models of propane-ready light trucks in the 1970s because of the economic advantages of propane in some high-mileage applications. When oil prices fell in the 1980s, OEMs ceased to offer propane-ready vehicles, although many conversions of gasoline and diesel vehicles by aftermarket converters continued to take place.<sup>24</sup>

Presently propane is used to fuel vehicles such as pick-ups, vans, medium duty trucks and buses, and forklifts. Many of the older vehicles are converted from gasoline, but manufacturers are now offering some propane-ready vehicles for upfitting. The vehicles would be covered by OEM warranties and service plans.

Both natural gas and propane are well suited to aftermarket conversions, which have provided by far the greatest number of these vehicles. In the U.S., future conversions will be complicated by greatly elaborated requirements for emissions certification. If the California proposal is a model, certification will require durability testing, as well as the acceptance of responsibility for warranties and potential recalls for defects related to emissions control components. Future conversions may be done in close conjunction with the original vehicle manufacturer, if at all. Therefore, conversions may not play a long-term role in the production of AFVs, although they are likely to be important in the near term.

##### **4.2.4.2.2 Air And Marine Sectors**

No developments in propane use in the air or marine sectors have been identified.

##### **4.2.4.3 Conclusions**

A variety of propane vehicles are available, either through conversion or as OEM vehicles. There is long experience with the technology worldwide, and Hawaii has experience with propane vehicles, most of which were produced through conversions. In fact, the City and County of Honolulu are proposing to convert 364 additional propane vehicles over the next seven years to help satisfy their National Energy Policy Act requirements (National Energy Policy Act requirements are described in Section 4.3.1).

Increased propane demand in the ground transportation sector would need to be satisfied by increasing imports of propane, increasing local refinery production (which would require increased importation of petroleum), or a redirection of the fuel away from current non-transportation consumers.

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<sup>23</sup> OEMs describe the vehicle as produced at the manufacturing plant.

<sup>24</sup> Aftermarket conversion is the process by which independent parties not associated with the original vehicle supplier install equipment to enable the vehicle to operate on other fuels.

## **4.2.5 ELECTRICITY**

### **4.2.5.1 Introduction**

“Electric vehicles” (EVs) are broadly defined as those which are propelled by electric motors. EVs come in many forms, such as:

- battery-powered vehicles (“battery-electric vehicles”);
- “hybrid” vehicles that use more than one form of energy storage and/or more than one form of propulsion;
- fuel cell vehicles that convert chemical energy directly to electric power; and
- vehicles powered by on-board solar cells.

EVs would allow transportation energy to be obtained from any fuel capable of producing electricity, such as fossil fuels, organic wastes, wind, solar, geothermal, and others. Which fuel would actually be used to power EVs is complicated, affected by such factors as:

- the time of day at which the recharging occurs;
- fuel prices;
- purchase agreements with independent power producers (IPPs); and
- the island on which EV recharging is proposed.

At present, much of the increased electricity would come from petroleum. On Oahu, some portion of the power could come from municipal solid waste (the H-POWER facility) and coal, and on the neighbor islands, some portion could come from biomass (such as bagasse-fired power generation units), hydroelectric, wind, and geothermal sources. Non-petroleum energy sources are currently under-utilized on Oahu and Hawaii during early morning hours when EV recharging is expected to occur.

In addition to their flexibility in fuel, EVs offer other advantages including:

- they can recover and store energy “wasted” during braking (regenerative braking);
- the power demand of an EV is greatly reduced when the vehicle is not traveling (stuck in traffic congestion);
- EVs do not emit air pollutants, a significant feature in downtown areas with poor air quality;<sup>25</sup>
- EVs are extremely quiet in comparison to internal combustion (IC) vehicles;<sup>26</sup>
- EVs are expected to have reduced maintenance in comparison to an IC vehicle; and

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<sup>25</sup> While combustion and resultant air emissions may have occurred to produce the electricity, the pollutants are emitted from the power plant stack which may be located in an area where air quality is not as great a concern as in a downtown location. It is also feasible and effective to place air pollution controls on the generating station stack.

<sup>26</sup> EVs are so quiet, in fact, that this may be a safety concern since people are accustomed to using a vehicle's sound as a cue to its approach.

- EVs may be amenable to small-scale manufacturing, since they are much simpler than an IC vehicle.<sup>27</sup>

Current barriers facing EVs include:

- their cost;<sup>28</sup>
- lack of standardization of such items as recharging systems, components, and batteries;
- lack of trained users and mechanics;
- public and fleet manager perceptions;
- issues associated with battery recycling;
- the lack of recharging infrastructure; and
- the poor ability to store sufficient energy on-board to provide both long range and peripheral features consumers want, such as air conditioning.

Battery-electric vehicles held significant U.S. market share in the earliest days of the automobile, but after the invention of the electric starter system for gasoline vehicles, the electric vehicle receded into small niche applications.

Vehicle applications appearing most likely for battery-powered EVs<sup>29</sup> include:

- small vehicles used in a localized area, such as Cushman three-wheelers used for parking enforcement or vehicles used in “new village” layouts,<sup>30</sup> industrial/commercial parks or retirement communities;
- “station cars” (cars that shuttle between home and a transit station);
- short-range commuter cars, vehicles used for short trips, shopping, short home-to-work commutes, etc.;
- delivery vans which experience substantial “stop-and-go” operation; and
- shuttle buses.

These are appropriate applications for initial EV deployment because range would not be a serious limitation, and the vehicle would return to a home base where a recharging station could be provided.

Hybrid vehicles combining electric drive and internal combustion engine systems show promise, and several vehicles of this type are being deployed in Hawaii as part of the Hawaii Electric Vehicle Demonstration Program (HEVDP). The engine on a hybrid vehicle (typically called an auxiliary power unit or APU) is operated over a narrow range of speeds, allowing

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<sup>27</sup> For example, EVs are being made on the Big Island (see footnote 33) and a Japanese firm, Itochu Corporation, has invested in U.S. Electricar, Inc., which expects to open a facility to convert conventional vehicles to EVs in Hawaii as part of the HEVDP.

<sup>28</sup> EVs are currently much more costly than conventional vehicles. EV offerings from major manufacturers in the late 1990's may be as much as \$10,000 more than conventionally fueled counterparts (Nichols, 1993). The pace at which costs will fall is a matter of intense disagreement between EV advocates and detractors. Additional EV cost information is provided in Chapter 6.

<sup>29</sup> Although many golf carts are electric, they are not legally classified as “motor vehicles” and, therefore, are not included in any of the proposed alternative fuel vehicle programs or incentives.

<sup>30</sup> New village land use planning concepts are discussed in Chapter 3.

optimization of performance and emissions characteristics compared to conventional IC engines. APUs could use gasoline, diesel or alternative fuels. For example, the 40-foot transit bus being deployed as part of the HEVDP is a hybrid electric equipped with a propane-fueled rotary engine. The range extension and performance boost provided by the on-board engine on hybrids may greatly enhance consumer acceptance of electric vehicles.

Hybrid-electric vehicles could have appeal in relatively heavy duty applications such as transit buses and trucks.

Fuel cells that combine gaseous or liquid fuels with oxygen in a chemical reactor to produce electric energy are currently in use as stationary power generators, and the U.S. Department of Energy (U.S. DOE) has researched fuel cells in transportation since 1987. In common with internal combustion (IC) vehicles, fuel cell systems require that chemical energy be stored on the vehicle. Gasoline, alcohol or propane are all suitable for fuel cells. Size and weight constraints, in addition to infrastructure and economic obstacles, need to be addressed before fuel cells can become a viable transportation technology. The U.S. DOE's program aims for sales of "first-generation" fuel cell vehicles by 2005 and sales of "fully competitive" fuel cell vehicles by 2011 (U.S. DOE, 1992c).

Some of the most "visible" electric vehicles are those powered by on-board panels of solar cells. These vehicles are often hand-crafted and designed to compete in solar car races. These vehicles have much to contribute to research and development, but they are not designed to meet the needs of commuters or fleets.

#### **4.2.5.2 Electric Vehicle Availability**

Much research, funding, and enthusiasm is being devoted nationally and locally<sup>31</sup> to developing practical electric vehicles, and the technology is developing rapidly with substantial government support. For example, areas of active research include:

- enhancing range;
- decreasing the time required to recharge;
- increasing battery life;
- increasing battery storage capacity;
- developing "flywheel" energy storage devices;
- developing full-featured vehicles;
- decreasing maintenance; and
- improving battery recycling technology.

OEMs have developed a few prototype or limited production vehicles, and are working to develop marketable production vehicles to satisfy the EV sales requirement in California of

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<sup>31</sup> DBEDT and the Department of Education started sponsoring solar vehicle competitions in 1988, and Hawaii hosted the national "EV '93" conference, which included the Pali challenge, a road rally of EVs over the Pali.

two percent of all light-duty sales beginning in 1998 (this requirement is discussed in Section 4.3.2). There are also many EVs being produced by specialty car companies.<sup>32</sup>

There are several governmental programs investing in EV research and development, such as the HEVDP sponsored by the Advanced Research Projects Agency (ARPA) of the U.S. Department of Defense. ARPA provided \$5 million of federal funds and other project participants provided \$5.5 million in matching funds in the first year to demonstrate 37 EVs on Kauai, Oahu, Maui, and the island of Hawaii, including such vehicles as transit buses, pick-up trucks, vans and sedans. This program is funding the establishment of the National EV Data Center at the University of Hawaii, and an electric vehicle facility on Cooke Street. In addition, the U.S. DOE has devised a multi-year program to assist industry to develop hybrid vehicles which meet consumer demands to the extent sufficient to make production financially worthwhile. According to this plan, production hybrid vehicles would be available by 2001 (U.S. DOE, 1992b).

### **4.2.5.3 Conclusions**

Hawaii has a mild climate that favors battery performance, limited vehicle range requirements, and a large supply of renewable energy resources capable of producing electricity. High levels of traffic congestion such as found in Honolulu also favor electric vehicles because they consume only the energy required to run peripheral devices (such as air conditioning) while stopped in traffic. Thus, Hawaii may offer more opportunities for electric vehicles than any other state. The promise of EVs is so attractive, and the governmental support of research and development is so strong, that future EVs may well compete successfully with IC vehicles in at least some applications. In the near term, however, issues such as vehicle cost and potential consumer concerns about the availability of opportunity charging remain significant barriers to deployment.

## **4.2.6 BIODIESELS**

### **4.2.6.1 Introduction**

Biodiesel is a vegetable-oil or tallow-based fuel with properties similar to diesel. The oils are typically obtained from oil seed crops such as rapeseed (in Europe) or soybeans (in the US), although other oil sources may be used, such as waste oil from fast food restaurants, fats from meat processing operations, and tropical oils. Several proprietary names exist, such as SoyDiesel, the product associated with the Missouri Soybean Merchandising Council, and Diesel-Bi, a product of the Ferruzzi-Montedison Group subsidiary, Novamont.

Biodiesel manufacturers recommend that it be blended with petroleum-derived diesel fuel in a blend of about 20-30 percent. This blend can be used in unmodified diesel engines, but biodiesel can erode rubber so rubber fuel lines are typically replaced, and injection timing should be adjusted (Ayers, 1993). In the U.S., trucks, buses, and a boat have all been operated on biodiesel. In Europe, Mercedes-Benz warrants its heavy-duty engines on biodiesel (Missouri Soybean Merchandising Council and Missouri Soybean Association, 1992).

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<sup>32</sup> Such as U.S. Electricar and the Suntera Solar Chariot Company of the Hamakua District of the Big Island. Suntera recently received state support for a bond issue. Suntera and U.S. Electricar are members of the HEVDP.

Biodiesels from non-waste oils are considerably more expensive than diesel. Biodiesel from used cooking oils could be considerably less expensive, although quantities would be limited.

#### **4.2.6.2 Biodiesel Fuel Use in the Ground and Marine Sectors**

Field tests to date have shown good performance, and have included the use of biodiesel in transit buses, utility vehicles, and trucks in Sioux Falls, South Dakota and St. Louis, Missouri. The Sunrider, a SoyDiesel powered marine vessel, completed a round-the-world expedition in September, 1994. Some use of biodiesel has been achieved in Europe through incentives and mandates.

#### **4.2.6.3 Jet Fuel From Biomass**

Biodiesel is a possible candidate for petroleum substitution as a commercial jet fuel. Its high cetane number (less than 50), low sulfur (reflecting the absence of sulfur in most biomass feedstock) and low aromatics content (resulting in low particulate emissions) makes it an attractive alternative to petroleum.

#### **4.2.6.4 Conclusions**

Biodiesel appears to be a very feasible substitute for diesel in both the ground and the marine sectors, requiring minimal engine modifications. The main barrier to biodiesel is its high cost, which depends in large measure on the feedstock price. The Honolulu Public Transit Authority (HPTA) has determined that a 25 percent biodiesel blend would increase their fuel costs by 33 percent.

### **4.2.7 HYDROGEN**

Hydrogen powered vehicles have been built, but they are not expected to be commercially available soon.

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## **4.3 FACTORS PROMOTING ALTERNATIVE FUEL USE IN MOTOR VEHICLES**

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### **4.3.1 FEDERAL POLICIES, PROGRAMS AND LEGISLATION**

Because of the economics of petroleum-based fuels in the U.S., the free market alone has not produced much use of alternative fuels in the transportation sector. During periods of very high oil prices and uncertainties about oil supply, propane and natural gas have made slight inroads. When oil prices decline, interest in alternative fuels also declines, except in a few

niches.<sup>33</sup> Therefore, in the U.S., legislation has been used to promote development and use of alternative fuel technologies.

Oil price and supply uncertainties of the 1970s stimulated passage of the Energy Policy and Conservation Act of 1975. This Act established a roll-in of fuel economy standards beginning with the 1978 model year (the Corporate Average Fuel Efficiency, or “CAFE” standards) with the intent of reducing oil imports. The fuel economy standard is now at 27.5 miles per gallon, and has slowed growth of oil use in transportation.

The Alternative Motor Fuels Act (AMFA) of 1988 allowed vehicles using alternative fuels to compute their fuel economy on the basis of gasoline consumed. The computation procedure<sup>34</sup> results in these vehicles having a gasoline fuel economy of 80 miles per gallon or more. The Alternative Motor Fuels Act was an explicit use of the fuel economy standards to encourage manufacturers to build AFVs. The Act was expected to be influential in shaping manufacturer choices because, at the time, the fuel economy standard appeared difficult to meet, especially for domestic manufacturers who had many customers who expected large vehicles. The Alternative Motor Fuels Act also required that federal fleets purchase AFVs to provide some market demand, and to serve as an example in fuel substitution. In some cases, Executive Orders exceeded the Alternative Motor Fuels Act requirements.

Financial incentives have been offered since the early 1980s for ethanol to be used as a motor fuel.<sup>35</sup> Incentive payments between 1987 and 1992 ranged from \$445 million to \$540 million per year. With these incentives, ethanol has captured about one half of one percent on an energy basis of the national consumption of motor fuel.

In 1992, Congress passed the EPACT, the strongest national statement ever made in support of alternative fuels. The EPACT sets national goals of replacing with alternative fuels 10 percent of conventional fuels by 2000, and 30 percent by 2010. The EPACT had a further goal that half the substitute fuels be of domestic origin.<sup>36</sup>

To meet this goal, the EPACT requires certain fleets, including those in Hawaii, to purchase AFVs in increasingly large numbers. The requirements, summarized in Table 4-6, target centrally fueled fleets of light duty vehicles up to 8,500 pounds (federal and state fleets and the fleets of businesses producing alternative fuels). Municipal and private fleets of light-duty vehicles may be targeted if national goals are not being met at certain milestones. The fleet requirements could yield about three percent substitution of petroleum fuels by 2010, although exemption provisions make a definitive estimate difficult.

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<sup>33</sup> Propane continues to hold a small market share in high mileage fleet vehicles, including some taxi and van fleets, even during periods of low oil prices.

<sup>34</sup> The alcohols were assumed to be used in the form of 85 percent alcohol and 15 percent gasoline, and flexible-fuel and dual-fuel vehicles were treated as running on alcohol half the time.

<sup>35</sup> Currently the incentive is a waiver of 5.4 cents of the federal excise tax on gasoline for blends of ten percent ethanol and 90 percent gasoline (“gasohol”). Alternatively, an income tax credit of 54 cents per gallon of ethanol can be claimed. Small producers (less than 30 million gallons per year) can claim an additional ten cents per gallon income tax credit.

<sup>36</sup> Defined to include nations with which the U.S. has free trade agreements.



**Table 4-6**

**National Energy Policy Act Fleet  
Purchase Requirements for New and  
Replacement Vehicles Which Must Be AFVs**

	<b>Federal Fleets<sup>1</sup></b>	<b>State Fleets<sup>2</sup></b>	<b>Fuel Provider Fleets<sup>3</sup></b>	<b>Private and Municipal Fleets<sup>4</sup></b>
<b>1993</b>	5,000			
<b>1994</b>	7,500			
<b>1995</b>	10,000			
<b>1996</b>	25% <sup>5</sup>	10%	20%	
<b>1997</b>	33%	15%	50%	
<b>1998</b>	50%	25%	70%	
<b>1999</b>	75%	50%	90%	20%
<b>2000</b>	75%	75%	90%	20%
<b>2001</b>	75%	75%	90%	20%
<b>2002</b>	75%	75%	90%	30%
<b>2003</b>	75%	75%	90%	40%
<b>2004</b>	75%	75%	90%	50%
<b>2005</b>	75%	75%	90%	60%
<b>2006+</b>	75%	75%	90%	70%

Source: National Energy Policy Act, 1992.

Notes:

- 1) Section 303(a); years = fiscal years.
- 2) Section 507(o); years = model years; conversions may be used instead.
- 3) Section 510(a); business or units whose principal business is to provide alternative fuels, or a producer of electricity, or an oil refinery, importer, or producer of at least 50,000 bpd if a substantial portion of the business is producing alternative fuels; year = model year; two year slip available for electric utilities purchasing electric vehicles.
- 4) Section 507(a); goals may be adjusted downward or slipped; invoked only if goals of 10% substitution by of 2000 and 30% substitution of 2010 are not projected to be met and practical and if fuels are available; alternative schedule starting in 2002 can be involved later if needed; years = model years.
- 5) Percentages refer to portion of new and replacement vehicles which must be capable of using alternative fuels.

The fleet purchase requirements are “fuel neutral” since they do not specify particular alternative fuels.

The EPACT also includes some financial incentives, summarized in Table 4-7, for vehicles up to 26,000 pounds and buses carrying 20 or more passengers. These incentives focus on offsetting initial capital expenditures for AFVs and fuel storage and dispensing equipment. These incentives appear to favor propane and natural gas over alcohol.

The Intermodal Surface Transportation Efficiency Act (ISTEA) was adopted in 1991 and continues the practice of the Federal Transit Authority (FTA) in assisting with the incremental costs of alternative fuel buses and fuel storage and dispensing equipment. The EPACT also authorizes funds for alternative fuels in transit applications.

Executive Order 12844 was signed on April 21, 1993 and increases by 50 percent the AFV purchase requirements for federal fleets as required by EPACT for 1993, 1994 and 1995.

Another federal program, the “Clean Cities Program,” is a voluntary program whose goal is to increase the number of AFVs throughout country and encourage the development of refueling infrastructure for alternative fuels. Cities wanting to be designated a “Clean City” are required to execute a Memorandum of Understanding signed by “stakeholders” and develop an implementation plan to increase the number of AFVs in the city. As of early 1994, there were six designated “Clean Cities.” While not yet designated a “Clean City,” Honolulu has an active program<sup>37</sup> which is working to meet the designation criteria.

#### **4.3.2 ENVIRONMENTAL REGULATION AS A STIMULUS FOR ALTERNATIVE FUELS**

Occasional attempts were made in the 1980s to require the use of clean alternative fuels to reduce pollutant emissions. These efforts eventually led to “fuel neutral” emissions standards that were challenging for gasoline and diesel engines. It is now believed that these standards will not force the use of alternative fuels (with one exception), although they present challenges for gasoline and diesel fuel.

The exception is that current California Air Resources Board (CARB) standards require that two percent of a manufacturer's sales in California must be “zero emission vehicles, or ZEVs” (electric vehicles) beginning in 1998. The fraction rises to ten percent by 2003. This provision has stimulated an intense effort by major manufacturers to develop commercially attractive electric vehicles that offer performance and costs similar to gasoline vehicles. California recently reaffirmed its ZEV requirement in the face of strong lobbying by major OEMs.

#### **4.3.3 LOCAL PROGRAMS**

Some states have adopted incentives promoting alternative fuels prominent locally, primarily ethanol and natural gas. They include excise tax exemptions, vehicle incentives, and sometimes fleet mandates keyed to specific fuels. These programs can be important in affecting local choices of alternative fuel technologies, and can effectively preclude gasoline and diesel fuel from competing in certain applications.

In Hawaii, incentives to promote alternative fuel use exist. For example, gasohol fuel is exempt from the state excise tax. There are also state deductions similar to EPACT for clean-fuel refueling facilities (Hawaii Revised Statutes, Chapter 235).

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<sup>37</sup> Those involved in the program include the City and County of Honolulu, HPTA, USDOE, USGSA, DBEDT, HNEI, PICHTR, HECO, BHP, and U.S. Electricar.

**Table 4-7**

**Financial Incentives in National Energy Policy Act  
for Alternative Transportation Fuels**

<b>Description</b>	<b>Amount of Credit or Deduction</b>
Income tax credit against the total cost of any electric vehicle	Maximum credit \$4,000
Tax deduction for vehicles using methanol, ethanol, natural gas, or propane <u>Gross vehicle weight:</u> <10,000 lbs ..... Trucks/vans between 10,000 lbs and 26,000 lbs ..... Truck/vans greater than 26,000 lbs and buses seating at least 20 passengers .....	Maximum amount of deduction <sup>1,2</sup>  \$2,000 \$5,000 \$50,000
Tax reduction for alternative fuel storage (at the point of dispensing) and dispensing facilities (not including buildings)	Maximum amount deductible <sup>3</sup> \$100,000
Tax credit for electricity produced from wind and "closed-loop" (dedicated) biomass	Amount of credit <sup>4</sup> 1.5 ¢/kWhr if sales price is 8 ¢ or less in 1992 terms; declines to zero at a sales price of 11 ¢

Source: National Energy Policy Act, 1992.

Notes:

- 1) Credits and deductions apply through 2001, then phase out at 25% per year for vehicles placed in service after 12/31/01.
- 2) Applies to entire vehicle cost for dedicated vehicles; applies to incremental costs for bi-fuel, dual-fuel, and flexible-fuel vehicles.
- 3) Expires 12/31/04; may be spread across several years.
- 4) For facilities placed in service between 12/31/93 (12/31/92 for closed-loop biomass) and 2/1/99, for a 10-year period of production.

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## **4.4 THE DISPLACEMENT OF PETROLEUM THROUGH ALTERNATIVE FUEL USE IN THE GROUND TRANSPORTATION SECTOR**

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### **4.4.1 INTRODUCTION**

The following analysis presents the resulting petroleum displacement of several possible scenarios. The focus of these substitution scenarios is the ground sector since significant substitution of aviation fuels is not expected during the period covered by this report.<sup>38</sup>

### **4.4.2 SCENARIOS**

A “zero alternative fuels” projection is developed for comparative purposes. Then, a “baseline” scenario is considered, and variations are superimposed on the baseline. The baseline includes all requirements of EPACT and Executive Order (EO) 12844 (see Table 4-6); ethanol blending into gasoline at a statewide average rate of 7.5 percent; adjustment of state and county fuel taxes to reflect the lower energy content of alternative fuels; reduced rates for charging electric vehicles off-peak; and implementation of Administrative Directive 94-06. No state or county mandates for alternative fuels, incentives for the production of alternative fuels, or incentives for the purchase of alternative fuel vehicles are included in the baseline.

An “aggressive” scenario assumes, in addition to the baseline conditions, an increased rate of purchase of alternative fuel vehicles which could be driven by a combination of state mandates, incentives, or standards (individual measures, possible means of funding, effectiveness, and costs are discussed in additional detail in later chapters).

An “aggressive plus maximum gasohol and diesohol use” scenario assumes all of the conditions of the aggressive scenario, plus ethanol blending into gasoline at a statewide rate of 10% and ethanol blending into diesel at a statewide rate of 30%.

The default rate of vehicle population increase is the rate from Chapter 2. As described in Chapter 2, this study’s reliance on existing transportation plans as the primary “driver” of future transportation energy demand is intentional, since it is not the purpose of this project or independently estimate future transportation activity. Development of a Hawaii-specific link between transportation and energy demand enables revisions of the energy demand projection whenever the underlying transportation projections are updated. However, to show the sensitivity of these estimates to a change in rate of vehicle population increase, a reduced

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<sup>38</sup> Although according to a Baylor University research team (Ninth International Symposium on Alcohol Fuels, Volume 2) certain cost and operational advantages may be realized with alternative fuel use in aircraft, the current low level of activity in this arena makes it difficult to propose any credible scenario which includes a significant penetration of alternative fuel use in aircraft.

rate is evaluated for both the “baseline” and “aggressive plus maximum gasohol and diesohol” scenarios.

In summary, the following scenarios are examined:

1. Baseline, with default rates of vehicle population increase;
2. Aggressive, with default rates of vehicle population increase;
3. Aggressive plus maximum gasohol and diesohol use, with default rates of vehicle population increase;
4. Baseline, with reduced rates of vehicle population increase; and
5. Aggressive plus maximum gasohol and diesohol, with reduced rates of vehicle population increase.

Evaluating scenarios such as these brackets a range of petroleum displacements that could occur. Assumptions may be altered and the results recalculated during the design of an implementation plan.

#### **4.4.3 CAVEATS**

The following caveats apply to the analysis:

EPACT schedules for AFV purchases may be changed or delayed in rulemaking.<sup>39</sup> The scenarios shown here assume full implementation of EPACT fleet purchase requirements.

Key limits to the aggressive scenario are the availability of alternative fuel vehicles (i.e. the manufacturers' willingness to provide alternative fuel capability as an option in their various car and truck lines)<sup>40</sup> and, most significantly, the rate at which available AFVs are purchased in Hawaii. Experience shows that this rate will be heavily influenced by:

- AFV technology, cost, and other elements affecting the relative attractiveness of AFVs to consumers;
- availability, accessibility, and cost of alternative fuels; and
- the level of public awareness and acceptance of AFVs as low-risk and/or socially-conscious investments.

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<sup>39</sup> Especially susceptible are the requirements for private and municipal fleets which do not begin until 1999 or, if rulemaking is delayed past 1996, until 2002. Further, start dates and roll-in percentages may be adjusted downward to account for constraints on fuel availability or on the availability of suitable vehicle models. If rulemaking is delayed past 1999, no requirements apply to these fleets.

<sup>40</sup> Those required in addition to national EPACT requirements.

#### **4.4.4 THE BASELINE SCENARIO**

In the baseline scenario (modeled for both default vehicle population increase and reduced rate of vehicle population increase) it is assumed that fleets on Oahu meet their AFV purchase requirements under EAPCT and EO 12844.

Only Oahu fleets are captured under EAPCT because the requirements only apply to Metropolitan Statistical Areas with a population of 250,000 or more in 1980. In addition, except for non-tactical military vehicles leased from the federal GSA, military fleets on Hawaii are excluded because they are considered “deployable” and therefore not required to be AFVs (Lt. Col. Gavel, personal communication). Rental car fleets are also not included under EAPCT requirements.

The default rate of vehicle population increase is the rate from Chapter 2. The reduced rate of vehicle population increase is roughly one-third the default rate.

#### **4.4.5 THE “AGGRESSIVE” SCENARIO**

In this scenario, it is assumed that state and other actions place AFVs in Hawaii beyond the requirements of EAPCT and EO 12844. The “aggressive scenario” assumes that most fleets in Hawaii acquire AFVs. The differences between the aggressive scenario and the baseline scenario are the following:

- fleets not captured under the National Energy Policy Act, such as rental car or small fleets, are captured under a local program; and
- vehicle purchase incentives and fuel production incentives are included.

Variations in the retention in-state of resold rental vehicles are also modeled. In-state retention is understood to be small (less than 20 percent) and variable. More precise figures could not be obtained (Annalise McKean-Marcus, personal communication; Hardy Hutchison, personal communication). Cases treated in this analysis include the baseline amount of 10 percent retention, which we consider plausible and likely, 50 percent retention, which we consider to be a high case, and 100 percent retention, shown to illustrate the maximum conceivable introduction rate from rental fleets. The impact of rental fleet retention rates on the results of the “aggressive” scenario is shown in Table 4-8.

#### **4.4.6 THE “AGGRESSIVE PLUS MAXIMUM GASOHOL AND DIESEHOL” SCENARIO**

The effects of implementing maximum substitution strategies in conjunction with the aggressive scenario are also estimated. These strategies are:

- all remaining gasoline vehicles are fueled by gasohol, a blend of 10 percent ethanol and 90 percent gasoline; and

- all remaining diesel vehicles are fueled by diesohol, a blend of 30 percent ethanol and 70 percent diesel.

Another potential substitution strategy, the use of biodiesel (up to 20% vegetable oil or tallow-based esters blended with diesel fuel) was not explicitly modeled due to lack of information on the feasibility and costs of large-scale local production. This option may be revisited when additional information becomes available.

#### **4.4.7 RESULTS AND CONCLUSIONS**

Table 4-8 shows projected displacement of gasoline and diesel in the ground transportation sector. Results of the main scenarios are shown graphically in Figure 4-1. The baseline scenarios displace approximately nine percent of gasoline plus diesel use by the year 2014. The aggressive scenarios displace much more, especially with higher rates of retention of rental vehicles. For the expected case of ten percent retention, the aggressive scenario displaces about nineteen percent of gasoline and diesel use by the year 2014. If maximum blend strategies are included, the displacement in 2014 is estimated at about twenty-two percent of the total ground sector consumption.

Due to the slow roll-in of AFVs even in the aggressive scenario, gasoline demand grows to about the year 2000 before a decline begins, which gradually reduces gasoline use to the 1995 level by 2004. Thus, using the default rate of vehicle population increase, even the most aggressive measures are not expected to take gasoline volume away, but simply capture the expected growth in gasoline demand.

However, if the rate of vehicle population increase is significantly less than the default rate, both the "baseline" and the "aggressive plus maximum gasohol and diesohol" scenarios show a decline in demand for gasoline and diesel. This indicates the importance of transportation projections to energy demand forecasting and alternative fuel demand estimates.

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### **4.5 THE DISPLACEMENT OF PETROLEUM THROUGH ALTERNATIVE FUEL USE IN THE MARINE SECTOR**

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Figure 4-2 shows the displacement of fuel used in the marine sector that would occur if all diesel was replaced with a 20 percent biodiesel blend. This analysis assumes that engines operating on residual oil would not use a biodiesel substitute, if only because residual oil is even less expensive than diesel, so that biodiesel-for-diesel substitution would occur first. These assumptions result in the displacement of about 700,000 barrels of diesel from the marine sector in 2014, with about 200,000 barrels of this displacement occurring in inter-island consumption.

**Table 4-8**

**AFVs in Operation in Hawaii and  
Gasoline and Diesel Potentially Displaced**

Scenario	AFVs in Operation by Year				Alternative Fuels: Total Demand in Millions of Gasoline Equivalent Gallons, by Year (and Percent of Total Ground Transportation Fuel Consumption)			
	1996	1999	2004	2014	1996	1999	2004	2014
<b>Using default rate of vehicle population increase...</b>								
<b>BASELINE</b>	205	993	14,036	56,989	<b>19</b> (4.8%)	<b>20</b> (4.9%)	<b>26</b> (6.2%)	<b>44</b> (9.6%)
<b>AGGRESSIVE</b>	662	8,477	44,395	167,019	<b>19</b> (4.9%)	<b>23</b> (5.9%)	<b>39</b> (9.5%)	<b>89</b> (19.3%)
<b>AGGRESSIVE + 50% RENTAL CAR RETENTION</b>	663	9,352	51,497	210,589	<b>19</b> (4.9%)	<b>24</b> (6.0%)	<b>42</b> (10.3%)	<b>106</b> (23.1%)
<b>AGGRESSIVE + 100% RENTAL CAR RETENTION</b>	663	10,445	60,376	265,057	<b>19</b> (4.9%)	<b>25</b> (6.1%)	<b>46</b> (11.3%)	<b>128</b> (27.8%)
<b>AGGRESSIVE + MAXIMUM GASOHOL &amp; DIESOHOL</b>	662	8,477	44,395	167,019	<b>31</b> (7.9%)	<b>36</b> (8.9%)	<b>52</b> (12.6%)	<b>102</b> (22.2%)
<b>Using reduced rate of vehicle population increase...</b>								
<b>BASELINE</b>	205	930	12,422	45,762	<b>18</b> (4.8%)	<b>18</b> (4.9%)	<b>22</b> (6.2%)	<b>33</b> (9.2%)
<b>AGGRESSIVE + MAXIMUM GASOHOL &amp; DIESOHOL</b>	640	7,898	39,511	133,413	<b>30</b> (7.9%)	<b>33</b> (8.9%)	<b>45</b> (12.4%)	<b>75</b> (21.1%)



Figure 4-1

Statewide Gasoline and Diesel Fuel Consumption by Scenario

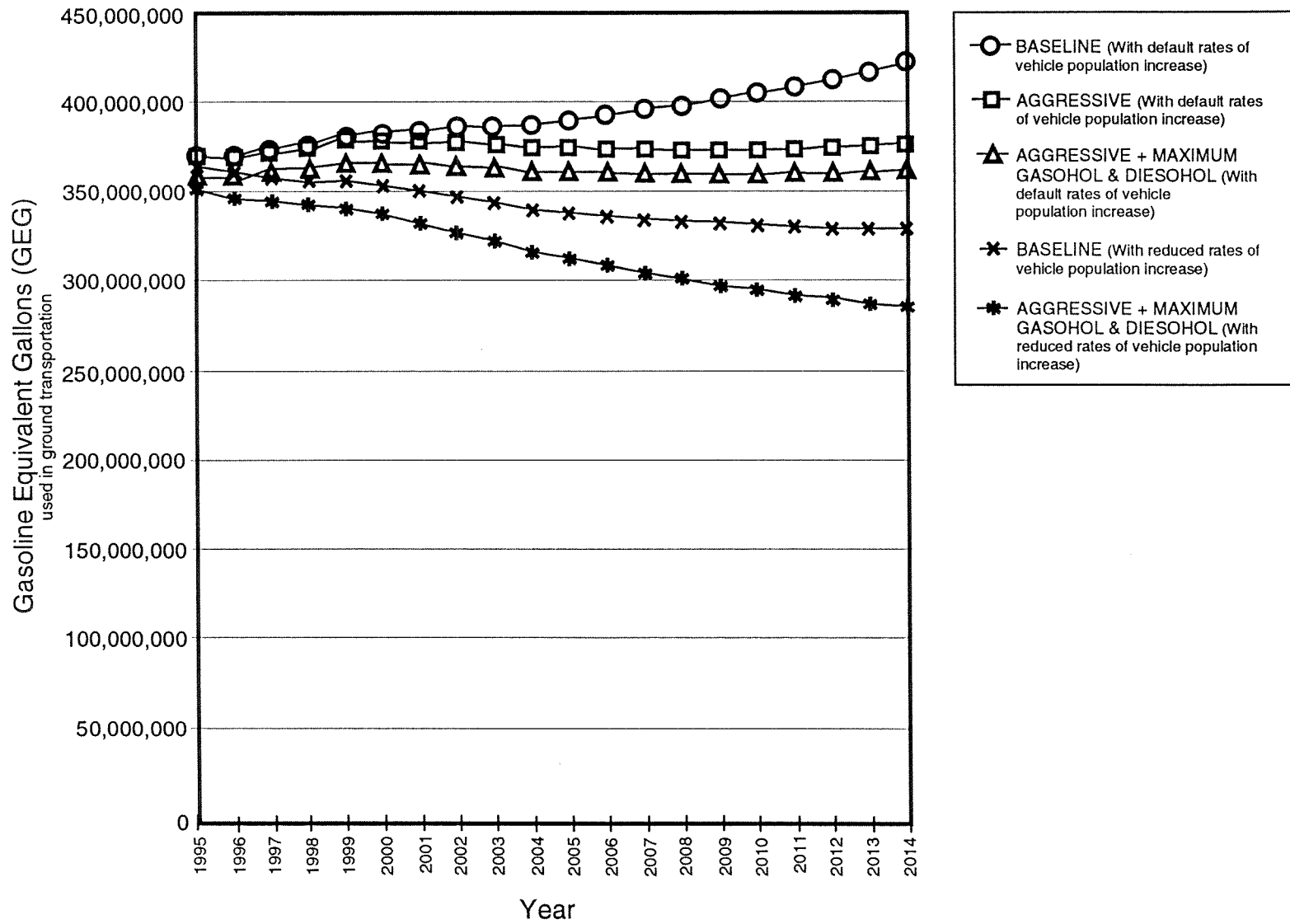


Figure 4-2

## Replacement of Marine Diesel by Biodiesels

